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THE FRALIT PROGRAM
(ERTS-1)

A REPORT PREPARED FOR THE OCCASION OF THE THIRTIETH
INTERNATIONAL AERONAUTICS AND SPACE EXHIBITION

P. DeMathieu and F. Verger

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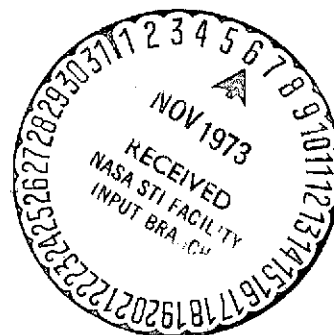
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THE FRALIT PROGRAM
(ERTS-1)A REPORT PREPARED FOR THE OCCASION OF THE THIRTIETH INTERNATIONAL
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P. DeMathieu and F. Verger

Already suggested when the first studies of teledetection were /1* made, interest in observation from space, for study of phenomena concerning water, vegetation, morphology, and surfaces of the Earth, has intensified even more since the Gemini and Apollo manned flights. Moreover, NASA established a program for study of Terrestrial Resources that was approved in 1969. The spokesman of the Committee of Science and Astronomy in the House of Representatives of the United States presented this project as an investment that could be more profitable than all the space programs of the past. With a desire for international cooperation, NASA has requested that other nations propose experiments within the framework of the program of technological satellites for study of the earth's resources: ERTS-1 satellites and then ERTS-B (Earth Resources Technology Satellite).

Several projects were presented by French teams under the auspices of the National Center for Space Studies (CNES). Among these, the FRALIT (FRench ATLantic LITtoral) project concerns the French coast on the Atlantic and the English Channel. It was accepted by NASA in the final months of 1971 and will have as associates the Ecole Pratique des Hautes Etudes (1), the National Geographic Institute (2), and the University of Poitiers (3).

I. General Features of the ERTS-1

The satellite ERTS-1 was launched on July 23, 1972 by a Delta rocket, from Vandenberg Base in California. The characteristics of this satellite that pertain to the FRALIT program are essentially its orbit, its schedules of passage, and the nature of the

*Numbers in right-hand margin indicate pagination of foreign text.

teledetection material on board.

Orbit

The orbit of a satellite intended for study of terrestrial resources should fulfill certain conditions. In effect, it is essential that photographs of various regions, or of a same region at different times, should be suitable for comparison among themselves; the scale should, consequently, be as consistent as possible, as well as the lighting conditions.

A consistent scale is almost achieved by a circular orbit. The ¹³ characteristics of the photography equipment, the desired scale, and other considerations led to choice of an altitude of 912 kilometers, which required a period of nearly 103 minutes, for the ERTS-1.

It is more difficult to achieve a lighting that is as invariable as possible: in order to do so, the angle of the Earth-Sun direction to the orbit pattern must be as consistent as possible. This was achieved by choosing an orbit that proceeds in the same direction and at the same angular speed as the average movement of the sun around the earth. (Nearly one degree per day). Calculations show that the orbit must, therefore, be retrogressive, with an inclination of 99.09° . Under these conditions, passage over a point on the lighted surface of the Earth occurs from the north-east toward the south-west, with the azimuth at the equator for the direction from which the satellite would come at 9.09° . All points of the Earth are covered, except those which are less than 9.09° from the poles (Figure 1).

Thus, it is necessary to choose the angle of the Earth-Sun direction to the orbit pattern. An angle of nearly 36° was chosen so that the time of the day in local time along the descending loop would be nearly 9: 42. For the different latitudes, the hour of passage (in local civil time) is slightly different from 9:42 because of the inclination, but this time only depends upon latitude. This does not mean that this condition would be true for legal time, since legal time is defined by conventional time zones. Thus, if it is supposed that the legal hour is the hour of the

time zone's schedule, and if the revolution n , representing the descending loop, is in the middle of a time zone, the legal hour would be equal to the local civil hour, or 9:42. On the next revolution, $n+1$, the descending loop is no longer in the same time zone, but is in a time zone situated two zones further to the West and the loop would no longer coincide with that zone's middle. The local civil hour is, therefore, always 9:42, but one can easily calculate that the corresponding legal hour is 9:25 ($9:25 + 103 \text{ minutes} - 2 \text{ hours} = 9:25$) and so on. . . For the revolution $n+2$, passage along the descending loop would occur at the legal hour 10:08 ($9:25 + 103 \text{ minutes} - 1 \text{ hour}$), for the revolution $n+3$ at 9:52, etcetera . . . Let us note that, if the local civil hour of the descending loop is constant, the corresponding true solar hour is not completely constant and can differ by fifteen minutes from the average. The same is true for the angle of 36° , which can vary several degrees.

Successive passages go toward the West by a quantity which, at the equator, is almost 2,869 kilometers. After 14 revolutions, that is, after 24 hours and a few minutes, the satellite no longer passes over the same spot as the night before, but 158 kilometers further to the West (always toward the equator) (Figure 2). As a result of this daily shifting, the zone included within two successive revolutions is swept into 18 days ($2869, 2/159,4 = 18$). In other words, all the parameters of the orbit are controlled and corrected in such a way that the coincidence is as close as possible, and we have seen that its passage would always occur at the same time.

Description of the Satellite

The ERTS-1 satellite uses the same structure as

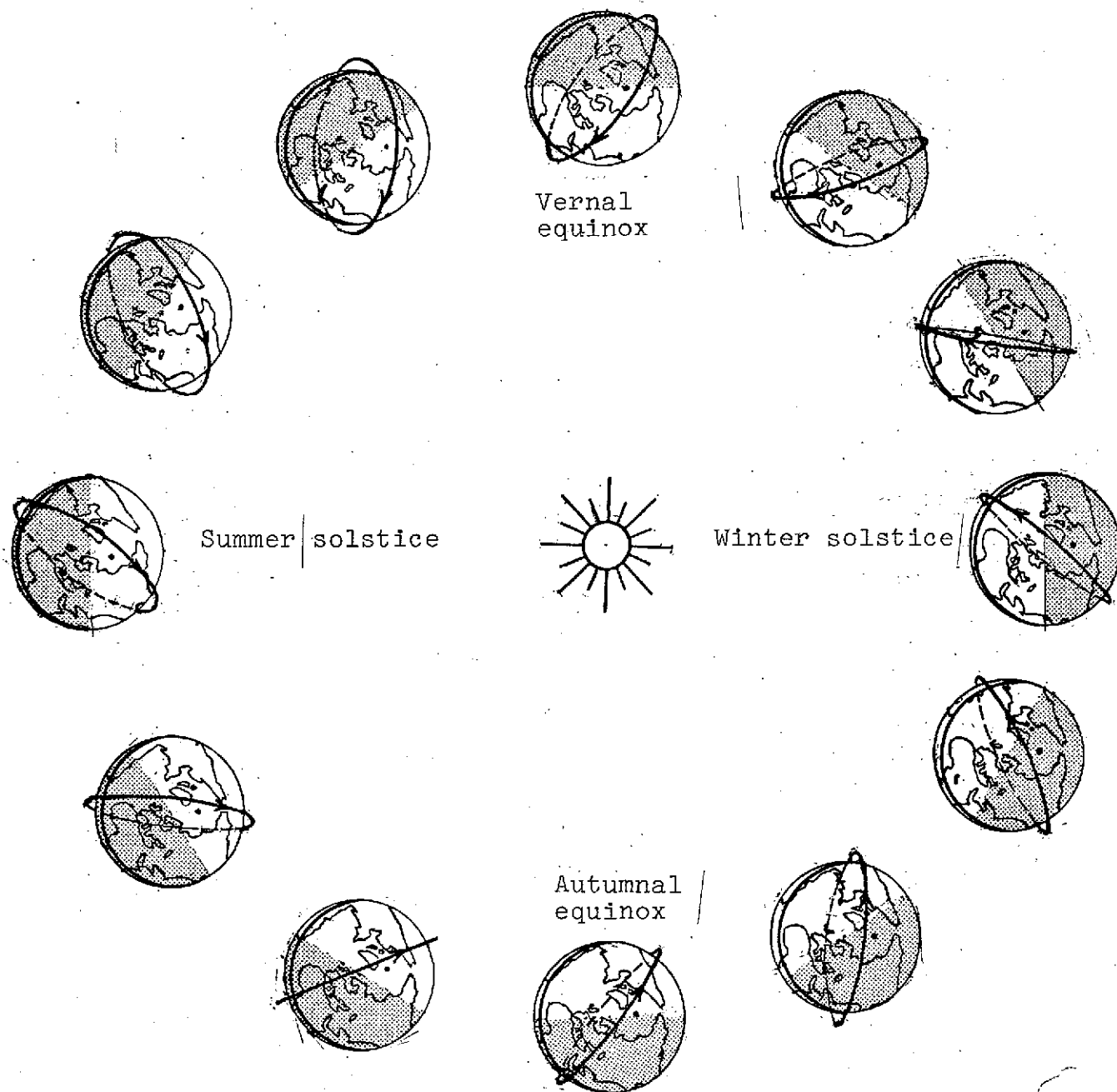


Figure 1. The orbit of the ERTS-1 Satellite. The figure has been prepared according to the plane of eclipse. The north pole, the equator, the shape of continents, and the seasons of the northern hemisphere have been indicated.

meteorological satellites of the Nimbus type. The "lower" portion, that is, the one which is constantly directed toward the earth by the system of altitude control, contains scanners and the electronic reception and sending equipment. The "upper" part contains the stabilization equipment, the altitude control, and the solar panels. Metal beams connect the two parts. The total weight is nearly 950 kilograms, the height is 3 meters, and the diameter is 1.50 meters, without the solar panels, but exceeds 3 meters when they are used (Figure 3). The axis of the photographic equipment should be very close to the vertical axis. This would offer control and eventual correction of rolling or pitching movements. Angular speeds of the movements according to the three axes are also examined and corrected. The active system that determines positions includes horizon sensors with a circular sweep, a gyroscope, three inertial guiders driven by motors and adjusted according to the axes of roll, pitch, and turning, in order to provide precise control. Gas vents assure necessary corrections. The precision obtained is .7 degrees for turning and .4 degrees for alignment of optical axes with the vertical axis. A system for measurement of position, which is purely passive and is independent of the preceding, is also installed; it permits knowledge of the position of rolling or pitching up to nearly .07 degrees for employment of this data.

The ERTS-1 satellite contains several systems of receivers: a group of three television cameras (Return Beam Vidicon or RBV) and a multispectral scanner (MSS).

The television cameras are equipped with tubes of a particular type characterized by the presence of a memory-bank that permits storing of the photograph after the closing of the shutter (during the opening = 12 milliseconds). The photograph

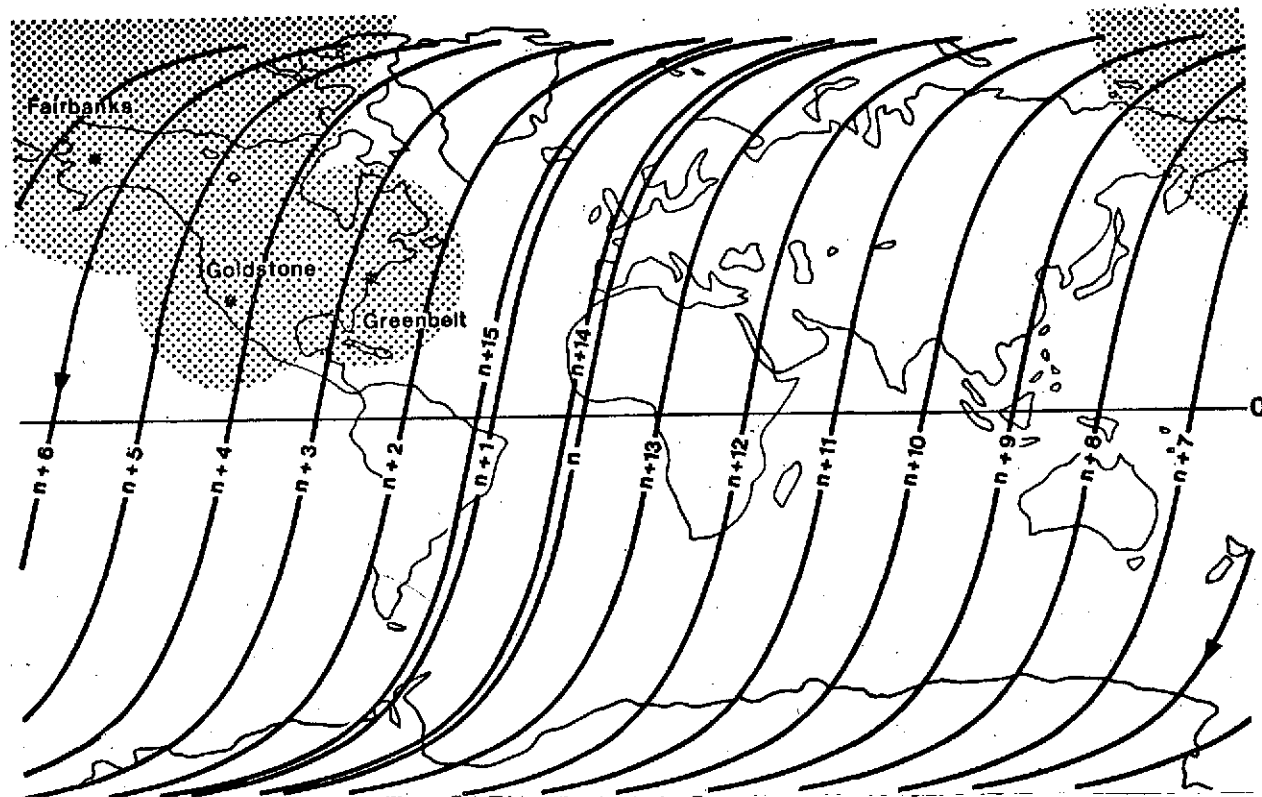


Figure 2. Passage of the ERTS-1 Satellite. Between the revolutions n and $n+1$, the movement of the descending loop is nearly 2869 kilometers to the West, and so forth for following revolutions. The revolution loop $n+14$ does not coincide with that of revolution n , but is 159 kilometers further to the West. The areas in which the satellite is in view from at least one of the three ground stations have been shown by dots.

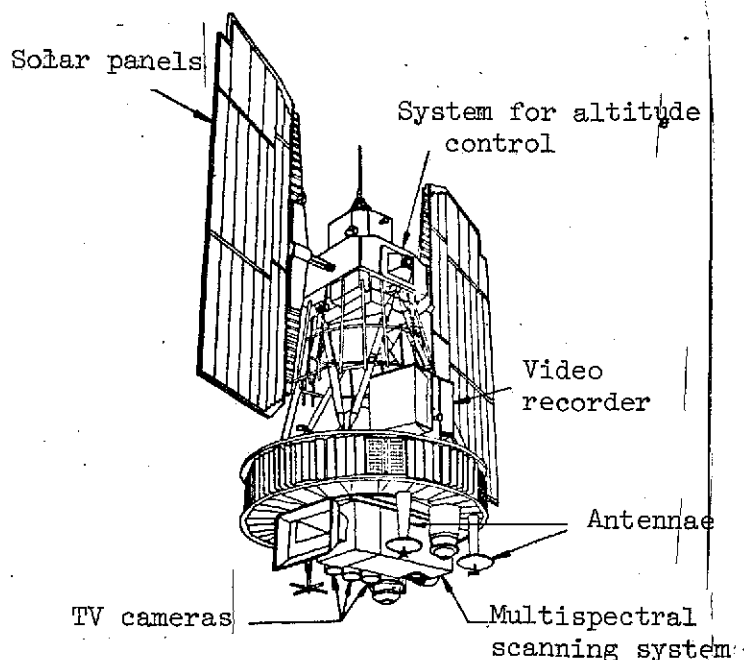


Figure 3. The ERTS-1 satellite (according to the Data Users Handbook of NASA).

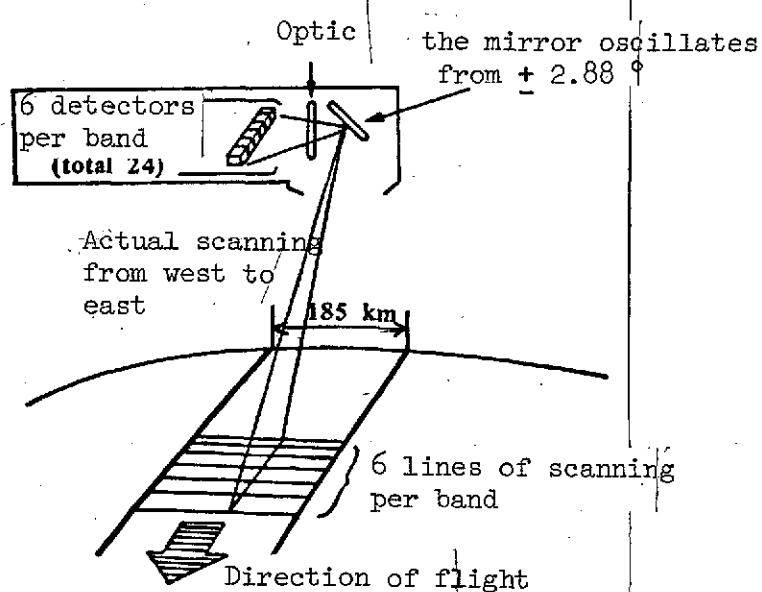


Figure 4. Data-gathering by multispectral scanning (MSS) (according to the Data Users Handbook of NASA).

is explored at the level of 1250 lines per second during 3.5 seconds; it is then erased by illumination and sweeping of the photoconducting surface by a cluster of electrons. The cycle is repeated every 25 seconds. Each camera operates within a well-determined spectral band.

NASA Code	Wave-lengths in nanometers	Colors
1	465-575	Green
2	580-680	Orangish-yellow to beginning of red
3	690-830	Red and beginning of infra-red.

The three cameras are set for "photographing" during the same instant the same terrestrial expanse of 185 kilometers by 185 kilometers. The television line of sweep corresponds to a band nearly 45 meters long at the ground-level. But the resolution, properly speaking, that is to say the minimal distance separating two objects that can be distinguished, is nearly 180 meters, if the contrast is weak, which can very often be the case. A high precision squaring (± 5 micrometers) appears on the photograph and permits findings and final measurements. Variations of photometric characteristics of the cameras are controlled during the course of the flight.

In the multispectral scanner, the image of the ground-level is sent within a telescope by a mirror that oscillates 2.88° at a rate of 13 periods per second. This scanning by perpendicular lines to the trajectory covers a band of the earth's surface that is 185 kilometers long (Figure 4). In the focal plan of the telescope, there are twenty-four

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cells, each of which is sensitive within one of the four spectral bands chosen, with six cells per spectral band. The presence of six identical groups permits sweeping of six lines in a single oscillation of the mirror. The length of such a line is 79 meters at the ground-level, approximately, and that of the six lines is 474 meters. The four spectral bands that are chosen belong to visible spectra and to near infra-red. The detectors that are used permit further coverage and the obtaining of a better differentiation within infra-red than the television cameras do. The bands are as follows:

NASA Code	Wave-lengths in nanometers	Colors
4	500-600	Green
5	600-700	Orangish to red
6	700-800	Red to infra-red
7	800-1100	Infra-red

The detectors are photomultiplying tubes for the first three bands and silicone photodiodes. A line 80 meters long at the ground-level involves a resolution of nearly 300 meters in practice. Information corresponding to a single spot of 80 meters x 80 meters on the ground is coded in words of 6 bits; the information flow is $2.5 \cdot 10^6$ bits per second. Auxiliary information concerning notably the synchronization for eliminating irregularities in oscillation of the mirror or for calibration of scales of density is transmitted to the ground.

Longitudinal recovery, that is between two successive photographs, exists for the television system. Photographs are made every 25 seconds; during this time, the satellite covers nearly 160 kilometers. Since the length of each photograph on earth is 185 kilometers in the direction of the

flight, longitudinal recovery is on the order of 25 kilometers, or almost 13%. For the system of multi-spectral scanning, there is no longitudinal recovery because it is a matter of a system of continuous sweeping. Transversal recovery, that is to say between two adjacent passages, is produced in the same fashion for the two types of receivers. Passages with a one-day interval are shifted 159 kilometers at the equator (compare below). This corresponds to a recovery of 14% at the equator. Recovery increases according to latitude: 34% toward 40° , 45% toward 50° , and 85% toward 80° of latitude.

Data

Transmission of data occurs according to real time if the satellite is in view of a ground station. If it is not, the data of the two systems are stored in the video registers which have a very long band of passage that permits an important space for information. Unfortunately, registration of RBV data diminished very quickly and that of MSS data ceased at the end of March, 1973. Thus, for France, ERTS-1 did not furnish any RBV documents and only transmitted MSS documents from August, 1972 to March, 1973.

Finally, platforms equipped with sensors that gather data on local conditions of environment at the ground level transmit the data to the satellite when it is simultaneously visible from the platform and from a station for tele-control and tele-measurement. These stations, which number three, are in Fairbanks (Alaska), Goldstone (California), and Greenbelt (Maryland); they possess necessary equipment for reception of data from the platforms (Figure 2).

Registrations of data are handled at the Goddard Space Flight Center (GSFC) in Greenbelt, from which they are diffused to the different users in the world. The documents can

receive a more or less elaborate treatment. The most simple level furnishes documents that have only undergone elementary corrections (System Corrected Image, or SYCI, formerly called Bulk Processing Subsystem). The most elaborate level furnishes clarification documents in which correction of errors is much greater and in which geographic and geodesic coordinates (UTM) are indicated (Scene Correcting System or SCS, formerly called Precision Processing Subsystem).

Errors can arise from external conditions or internal conditions in registration; the former include, for example, a bad alignment of the receivers, a defective position, an error in timing, et cetera . . . the latter can include optical distortions, electromagnetic variations of the television cameras . . . In addition, other errors can occur during handling of information. If, for the less elaborated data, errors are weaker in the multispectral system than in the television system, for precision data, it is the television system that furnishes the weakest errors. For example, for films, residual errors from ground position can reach the following values:

	Data after simple treatment (SYCI)	Precision data (SCS)
Television system (RBV)	1120 m.	95 m.
Multispectral scanning system (MSS)	1075 m.	235 m.

Data from the multispectral scanner undergo cutting which permits their geographic coincidence with the photographs from the television system. Data can be obtained either in the form of a photograph on film, or in the form of tape recordings. In the following tables, existing conditions for the nature and presentation of data are indicated by x's. Moreover, the x has been circled when the particular combination has actually been used within the FRALIT program:

Photographs on Film

Code	M	N	S	T
	Negative Film	Positive Film		
Format	70 mm.	9.5 in.	70 mm.	9.5 in.
Approximate Scale	1/336900	1/100000	1/336900	1/1000000
SYCI black and white	X		X	X
SCS black and white	X	X		X
SCYI colors				X
SCS colors				X

Magnetic Tapes

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Code	7	9
	7 tracks	9 tracks
	556 bits per inch	800 bits per inch
SYCI	X	X
SCS	X	X

II. The FRALIT Program

The agreement made with NASA projected, on the one hand, American supplying of documents obtained from the ERTS-1, and, on the other hand, relaying of studies made on these documents by French laboratories. This agreement, concluded under the auspices of the National Center of Space Studies (CNES), did not include any granting of funds, and NASA, together with the French laboratories, had to pay for the costs of its own contributions.

This program involved study of the marshy coastal areas along the ocean shore-line of France, as well as sedimentary materials in the water bordering these areas.

The area covered under the FRALIT project represents a quadrilateral whose four corners have the following coordinates:

50°30' N	2°00' W
51°00' N	2°00' E
44°19' N	0°35' W
44°51' N	3°42' W

This quadrilateral extends from Cap Gris Nez to the south of the Arcachon Basin; it cuts across the major portion of France's ocean coastline. It covers, in this way, the largest zones of sea-marshes with the exception of Flanders (Lowlands of Picardy, the Dol marshes, the Breton, Poitou and Carentan marshes), the largest inlets (bays of Somme, Veys, Mont Saint-Michel, Bourgneuf, and the Aiguillon inlet, the Carentan channel, and the Arcachon basin), as well as the three largest French estuaries (Seine, Loire, and Gironde). This quadrilateral does not include the Breton peninsula west of the Port-Navalo-Erquy line. Inclusion of that region would have greatly increased the number of documents to be examined, but would have been of little relevance to the regions which commanded our attention. The same is true of the coast of the Landes south of the Arcachon Basin.

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Data

The situation of the latitude of the FRALIT program involves certain consequences. The legal time of passage calculated as a function of the local civil time for the descending loop (9:42) is nearly 11:25. When this schedule

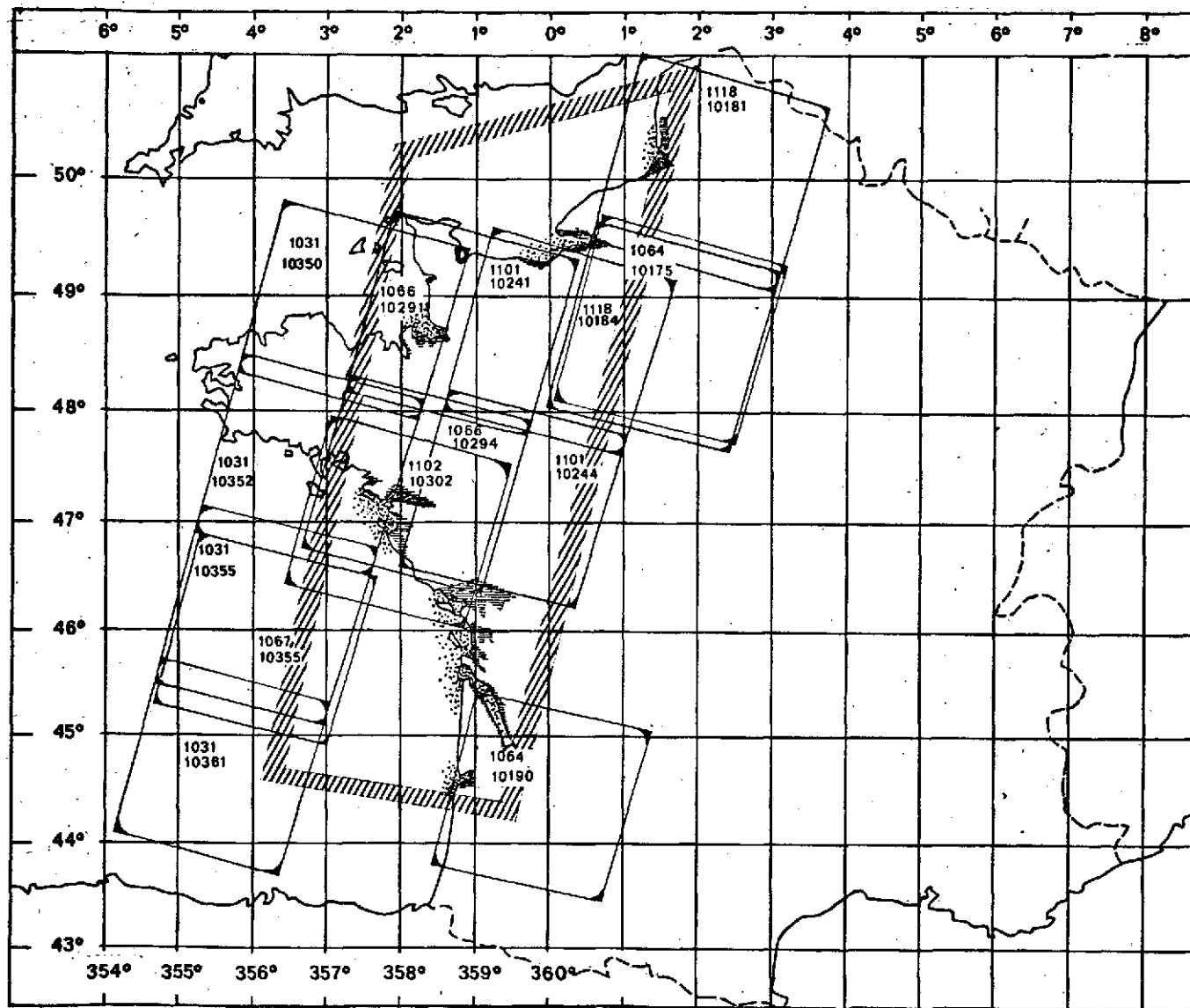


Figure 5. Coverage of the FRALIT program and localization of photographs received. (1) Envelope of the FRALIT program, (2) identification numbers for photographs, (3) zone of shore-line sedimentary deposits, (4) zone of salt marshes.

and the latitude are taken into account, the height of the sun above the horizon varied during the satellite's coverage of France from 16° almost to 50° . Of course, results were better, on the same date, for the South than for the North under the FRALIT program. It is generally considered that the quality of information declines if the sun is less than 30° above the horizon, as occurs from the end of October to the end of February. However, this general consideration is sometimes invalid because of particular circumstances connected with problems mentioned and meteorological conditions.

It has been estimated that the documents are not usable when the cloud cover exceeds 6/10. Thus, NASA only furnished documents obtained with a cloud cover lower than 6/10.

Meteorological conditions were rather unfavorable during the second half of 1972 and the actual capacities of the recording systems of the ERTS-1 satellite meant that the number of photographs obtained under the FRALIT program would be relatively low. The fourteen photographs received before May 1, 1973 do not cover the entirety of the coastal region concerned (Figure 5).

Documents of the FRALIT program were provided by NASA without corrections for precision, for the precision documents, which are much more difficult to obtain, did not seem necessary to the research that was planned. Precision photographs would seem more appropriate for establishing interpretation tests in the domain of littoral teledetection than for preparing a geometrically rigorous charting of the phenomena that have already been studied extensively at the ground level. In other cases, the objectives pertained to sedimentology and oceanography of the shore line, and the degree of precision

TABLE: Classification of Study Techniques Employed in the FRALIT Program

FRALIT program				Initial data	Colored Film	Magnetic Tapes	Techniques of Study using: Separate spectral bands* Combined Spectral Bands 0	Specific Material
U	Q			+			*Examination by transparency	Light table
S	U							
E	A			+			*Photographic re-inforcement	Photographic Laboratory
	L							
O	I			+			*Photographic Enlargement	Photographic Laboratory
F	T							
	A							
D	T			+			*Selection of areas of equidensity	Photographic Laboratory
A	I							
T	V			+			0 Multi-band combination of areas of equidensity	Photographic Laboratory
A	E							
				+			0 Projection of composite false colors	Photographic laboratory and multi-band viewer
				+			0 Printing in composite false colors	Photographic laboratory and offset press
					+		0 Examination by transparency in composite false colors	Light table
U	Q	P	D	+			*Microdensitometry of transects	Joyce Loeb1 3 CS microdensitometer
S	U	H	E					
E	A	O	N	+			*Microdensitometry of areas	Joyce Loeb1 3 CS microdensitometer
	N	T	S					
O	T	O	I	+			*Microdensitometric isophotometry of areas	Joyce Loeb1 microdensitometer with isophotometric component
F	I	G	T					
	T	R	Y					
D	A	A	P					
A	T	H	E					
	I	I	C		+		*Frequency statistics	IBM 360 computer
A	V	I	C		+		*Numbered transects	IBM 360 computer
	E	C	E		+		*Numbered charts	IBM 360 computer
	B	E	I		+		0 Correlation statistics for several channels	IBM 360 computer
	Y	N	V					
	M	E	D		+		0 Automatic thematic charting	IBM 360 computer and tracing table
	E	R						
	A	G						
	N							
	I							
	N							
	G							

of documents that had only undergone simple treatment was considered sufficient. Finally, precision treatment could be performed if the need for it were to arise later.

No RBV data could be obtained for the FRALIT program, but all the photographs were received in the four bands of the MSS 4, 5, 6, 7 system, except for one which only covered three of the bands. All the photographs were provided under the form of black and white film. In addition, one of them was provided in false composite colors and on magnetic tapes. Other documents (magnetic tapes, linear density photographs) were requested from NASA and will probably be received in the near future.

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Photographs received are of a very uneven degree of interest according to their localization and the cloud cover. Some only showed absolutely uniform sea expanses, while others showed uncovered land expanses or coastal areas hidden by clouds. Only one photograph showed no clouds at all, and two others presented vast uncovered coastal areas. Treatment essentially involved these three particular photographs.

Techniques (see the Table)

In all cases, photographs received were examined to determine which would be for later study and which additional requests should be submitted to NASA. The preliminary examination was carried out by transparency on a light scale, first for the initial films and then for the enlarged films that had been reinforced in their most interesting portions, as in the case of coastal deposits. Reinforcement of certain nuances allowed revelation of phenomena that were hardly recognizable in the original photographs. These preliminary efforts were carried out spectral band by spectral band, and only the results of interpretation derived from them can integrate

the information drawn from different spectral bands.

The photographic method based upon equidensities permits isolation of the given values of gray on the photographs. This selection facilitates the logical drawing of information furnished by each spectral band and then from the combination of bands. Thus, waters full of mud appear within a sector of the bay of Bourgneuf showing the same gray as the sea-pines along the coast of Monts on the MSS 5 photograph. The MSS 7 photograph allows distinction between one and the other since the water, even when it carries a great deal of mud, shows up very dark, whereas the pines are represented by a medium gray. This example is very schematic since, in reality, there are a great number of values for gray and there are four spectral bands.

In order to capture the information furnished by several bands at the same time, it is necessary to make efforts to examine photographs in composite colors. Moreover, it is a matter of the colors chosen in order to facilitate interpretation, the so-called "false colors," which correspond in certain cases to portions of the spectrum that are not visible. The most simple means of examination employs transparent films composite in false colors that have been furnished by NASA. These films include the data either for:

- bands 4, 5, and 6, or
- bands 4, 5, and 7 of the MSS system.

In the latter case, for example, data is translated by the following false colors:

- MSS 4: yellow
- MSS 5: magenta
- MSS 6: prussian blue

These colors combine in order to give a composite image. This

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relatively easy method offers a combination that one cannot modify further.

A more flexible system consists of simultaneous projection, in the various colors, of photographs taken from different spectral bands on the screen of a viewer called the: multiband viewer. This method permits modifications at will of the colors, and the intensities of each elementary image. The films used in this process are usually treated photographically before projection (notably by adding of masks).

A third method, finally, consists of combining the various false colors by printing. Here, again, it is useful to proceed to photographic operations before fixation in order to allow more easily the evaluation of phenomena considered to be the most interesting.

All the techniques described previously are qualitative. When magnetic tapes are not available, it is possible to attempt to measure photographic density of the films with the aid of a micro-densitometer. Microdensitometer measurements can be taken according to the rectilinear axes, and one, thus, obtains transects of photographic density (Figure 6), or, if they are taken for definite areas, one obtains charts of photographic density (Figure 7). These techniques employed for the FRALIT program permitted a useful approach for quantitative methods.

However, in order to arrive at precise quantitative measurements, and, in particular, to study in a careful manner the correlations between different spectral bands transmitted by the four channels of the MSS scanning system, it is preferable to use numerical magnetic tapes from NASA. These tapes contain, in effect, the totality of information received; this is not the case with photographic retranscriptions.

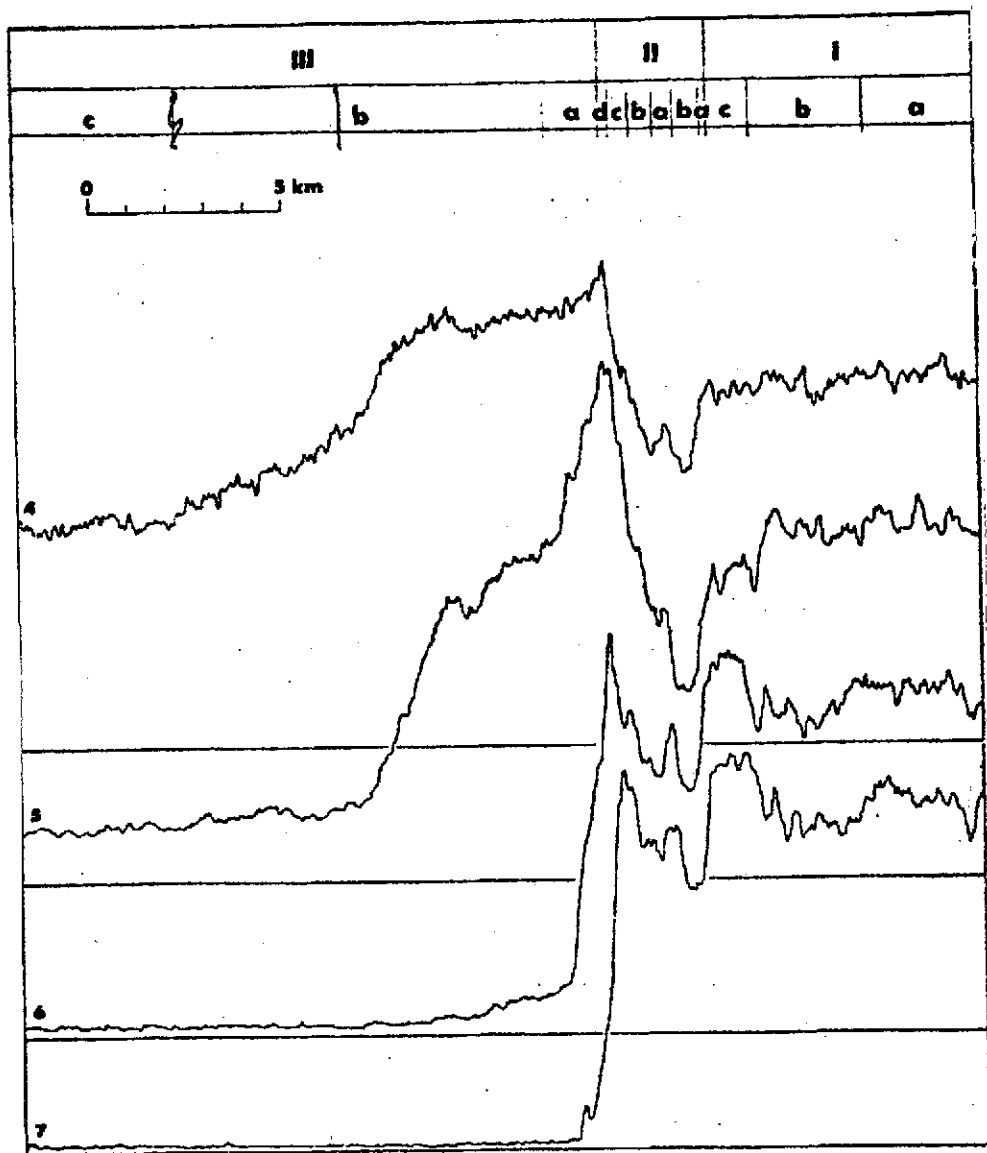
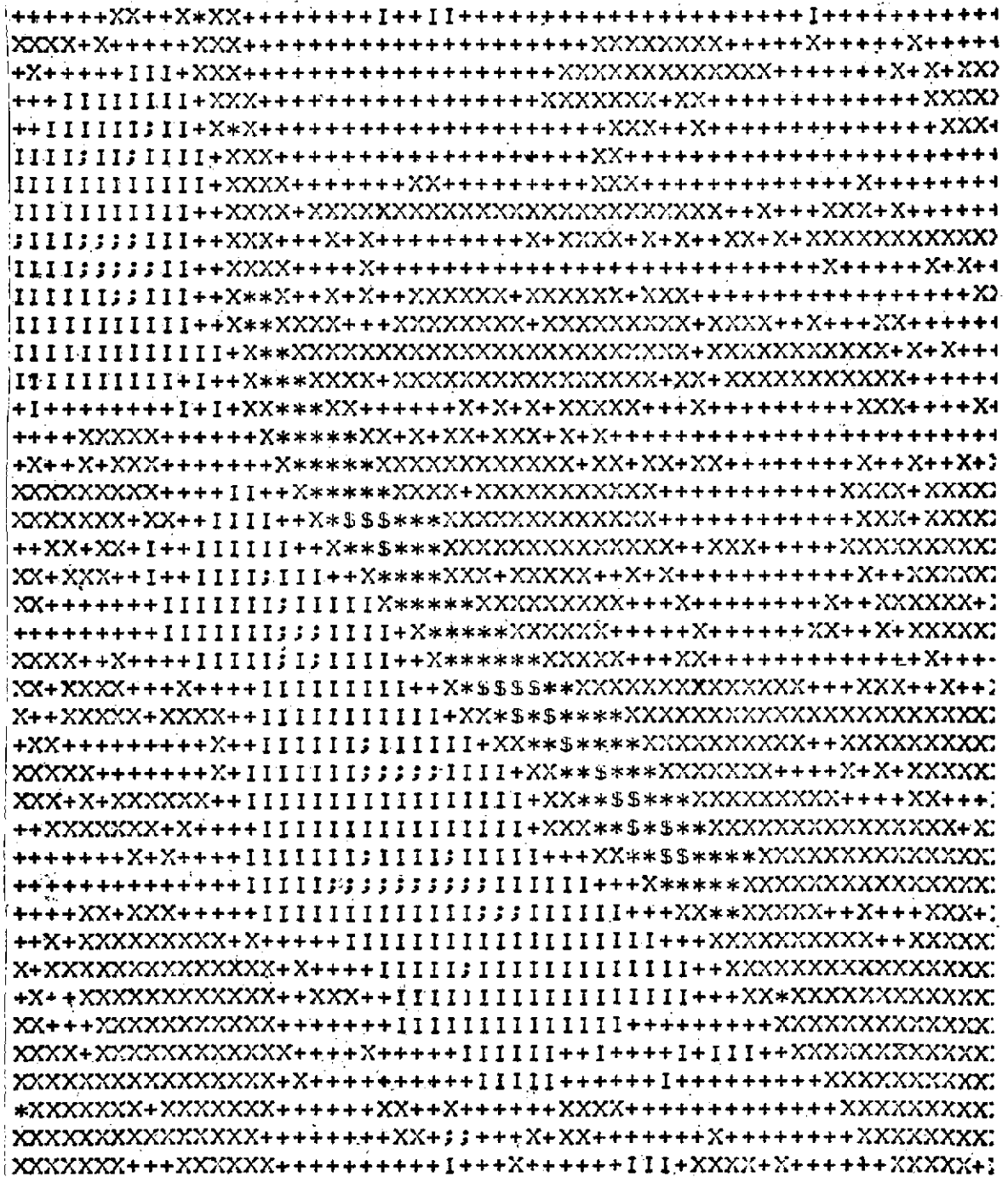


Figure 6. Microdensimetric Transect with multiband MSS, 4, 5, 6, and 7 (Joyce-Loebl microdensimeter, 3 CS). The areas distinguished are the following (Teledetection descending by marsh areas): (1) The marshes of Monts: a) coastal plain with permanent meadows, b) former salt marshes, c) Cultivation; (2) Beaches and dunes of Monts: a) gardens, b) forests of sea-pines, c) dune with psammophytes, d) beach; (3) Atlantic Ocean: a) highly turbid waters (under water delta of Fromentine, b) highly turbid waters, c) waters with low turbidity.

Figure 7. Excerpt from a microdensitometric chart obtained from an MSS 4 negative (Joyce-Loebel 3-CS microdensitometer guided by a PDP 8/E Digital Computer). The above document represents the coast of Saint-Brevin-L'Océan (Loire Atlantique). The zone of villas and woods extending north and south of Bologne is represented by I's, the sand beach of Saint Brevin L'Océan by #,s and \$. The vertical scale of the document is very lightly different from the horizontal scale. Both are close to 1/25000.



In the initial phase, numerical treatment is performed channel by channel: it consists of a statistical study of the frequencies of energy received, of visualization of certain transects and certain zones. This is only in preparation for the second phase, which is multispectral in the sense that it examines correlations for energy received within the different channels. After a statistical study of correlations, decision processes occur in order to distinguish automatically among the different geographical measurements retained: sea waters classified according to their turbidity, mud beds, beaches, rocky inlets, shoreline dunes, salt marshes, as well as forests, cultivation, rock formations, towns, et cetera . . . in such a way that cartography is automatically performed (Figures 8 and 9).

Initial Results

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Utilization--which is still only in the initial stages--of the documents furnished by the multispectral scanning system has been extremely productive with regard to the specific areas of the FRALIT project with regard to shoreline deposits, geomorphology of the inlets, and geography of salt marshes.

Shoreline Deposits

The sedimentary mass that forms the marshes and the waddens of the seacoast of France is very high and one must confront the problem of its geographic origin. Correlations attempted between present deposits in the waddens, such as the bay of Bourgneuf and the l'Aiguillon inlet, and the solid - deposits within rivers that flow into them have established the impossibility of an immediate exclusively fluvial origin. Qualitative methods, such as mineralogical analysis of mud, have shown a mixing of autochthonous and allochthonous sediments. Also, it is hoped that itineraries for the traveling of sediment

within the least deep waters of the shore zone can be established. Measurements of turbidity that are taken at sea have the advantage of great precision, but they remain far too sporadic to give an over-all view. Even aerial photographs, whose interest is often diminished by light reflection, must be brought together in order to cover broad areas, and their information is disparate.

The morning hour of passage for the ERTS-1 and its high altitude which allows simultaneously for a minimal opening of the sweep angle and a great length of ground-surface to be scanned permit acquisition of synoptic photographs over vast expanses. Especially, the multispectral system allows isolation of information concerning surface waters which is furnished by channel 4 and also by channel 5. One can then establish a chart of sedimentary levels, at the moment of the satellite's passage, for the Loire estuary, the Bourgneuf bay, and the Fromentine inlet. For example, mud-bearing waters from the bay of Bourgneuf passed through the Fromentine inlet on September 27, 1972 producing a very remarkable mixture on the MSS 4 and MSS 5 photographs. In the same way, photographs of the bay of Mont-Saint-Michel show a sort of puff of blackness which passes around the point of Grouin toward the North-West when the tide recedes. In this area, it is certain that teledetection from space contributes very new information concerning sedimentary transportation along shorelines, and it would be hoped that documentation is increased so that there will be an availability of documents concerning the various tidal levels (high tide, low tide, disturbed waters, still waters . . .). Understanding of these mechanisms is not devoid of practical interest for coastal protection. It is necessary for such measures as building jetties (which could accelerate or delay it) as well as controlling transit of sediments in suspension that could possibly be vectors of pollution.

In this area, the study of four channels is necessary. Channel 7 gave precise information on the humidity of the inlets and the sea limit at the moment of passage of the satellite. Channel 4 allows identification of different types of sediments: sand, pitch, mud; it was possible to map, to 1/50000, the sandy beaches revealed by the satellite's passage from the data for channels 4 and 7. Although other characteristics of the inlets were studied, such as the progression of mud-flats or salt meadows from the bay of Mont Saint-Michel. These investigations produced an automatic charting of sediments, hydrology, and, by deduction, hypsometry of the alluvial inlets. ERTS-1 furnished very useful information for coastal protection, therefore (mussel beds, oyster beds, use of beaches, et cetera).

Geography of Salt Marshes

In this latter instance, study of geomorphology was inseparable from familiarity with the environment: natural vegetation, cultivation, human procedures . . . Use of multispectral information permitted charting of zones of turf and muck in the Dol marshes, charting of present-day and fossilized borders in the Monts marshes, zones of old salt marshes, et cetera . . . Comparison of data for channels 5 and 7, which is presently being carried out, would permit suggestion of a classification of sea marshes based upon their geographical occurrence and their humidity. It is only after a certain statistical refinement that the cartographic representations obtained will be truly satisfactory. It is necessary to point out that the duration of the life-span of the recording system did not permit coverage of a year cycle, but future experiments will, some day, fill this gap.

Finally, if the efforts of the FRALIT program have

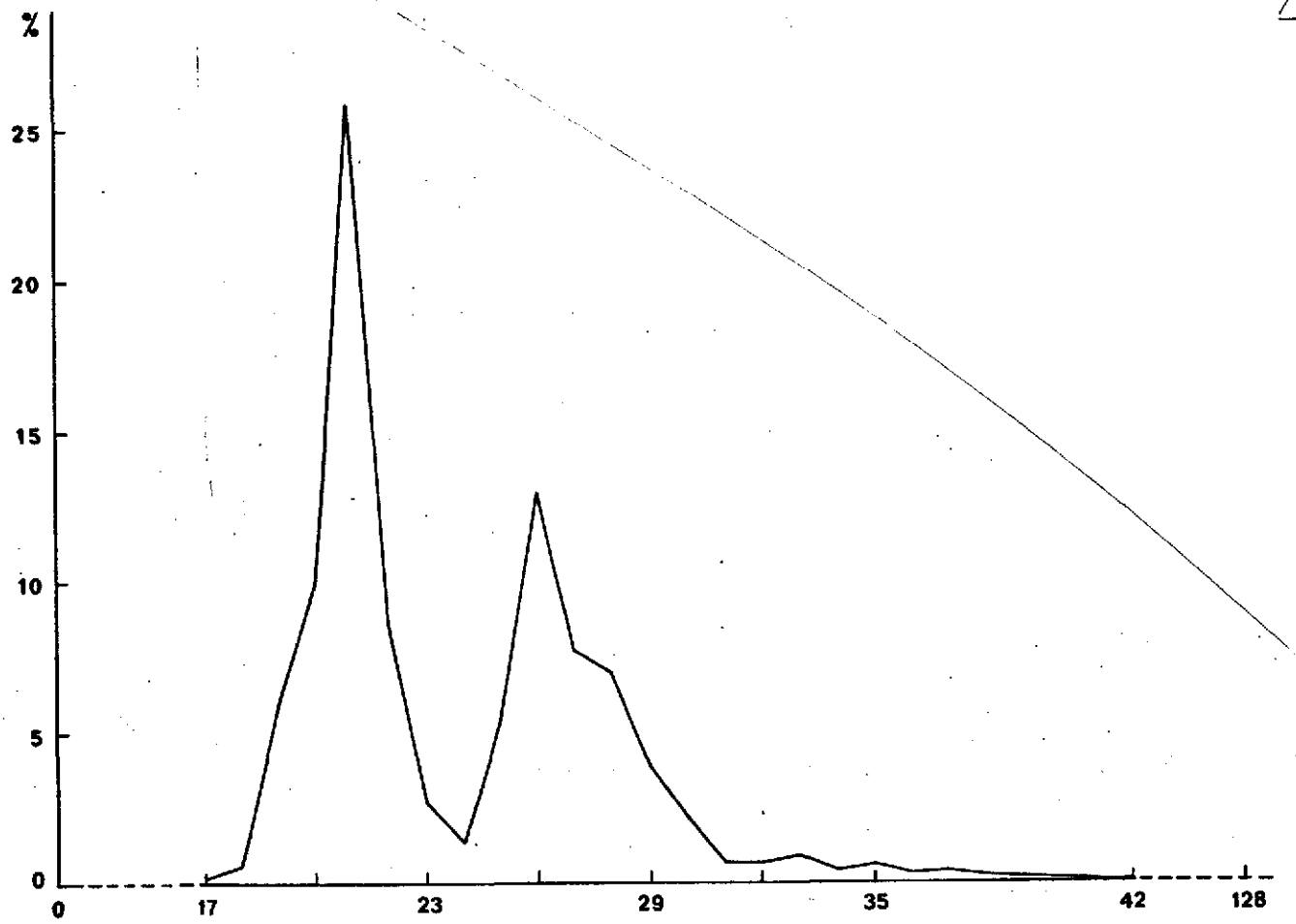


Figure 8. Polygon for frequency of energy levels received by the multispectral scanning system in channel 4 (photograph E.1066.10294.4; strip 3) Scanning of 20200 unitary pieces of information).

specifically involved the shore area, the documents are sometimes usable for recognition of various continental phenomena that are of interest to study of the Earth and its resources; it is necessary, in addition, to examine them in order to arrive successfully as discernment of coastal taxons that could show spectral signs that are closely related.

Conclusion

Teledetection from the automatic satellite ERTS-1 has presented numerous advantages. First of all, the data have been furnished in four spectral bands for each unitary area of information. When an ordinary black-and-white photograph only furnishes one value of gray for each point, the ERTS-1 furnishes four values whose combination can constitute extremely useful information. This very usefulness requires establishment of increasingly complex charts and increasingly precise spectral signatures for the different faces of the Earth's surface. The pluridisciplinary team for the FRALIT program is presently dedicating itself to this task of collecting and verifying information keys for the area of the sea-coast of France.

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Secondly, the data are numerical and use of such a mass of information can only be derived precisely by automatic means. Photograph negatives taken from numerical data are, moreover, not useless because they permit inexpensive determination of areas for study, facilitation of initial development of analyses, and introductory elaboration of the logical processes of interpretation.

Finally, the documents are homogeneous for large expanses on account of the altitude of the receivers, the smallness of the sweep angle, and the speed of the orbital trajectory. This homogeneity, the dimensions of the unitary region for

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information* and, the possibility of statistical refinement of numerical data permit, on the taxonomic scale, an increased familiarity with the Earth's surface, with much greater ease and, especially, much more certainty than can now be hoped for by cartographic generalization with reduction of high points to a large scale.

Multispectral data, once they have been numbered, and when they are homogeneous for vast expanses represent the ERTS-1's great potential for teledetection of terrestrial resources. They provide, for recognition of shore-line phenomena, a tool that is even more valuable, since surface observations are often difficult.

*This unitary region consists, on the ground, of a square of 79 kilometers of coastline. The squares are covered lightly in the direction of scanning because there is one every 56 meters, but they are juxtaposed in the direction of the satellite's trajectory.

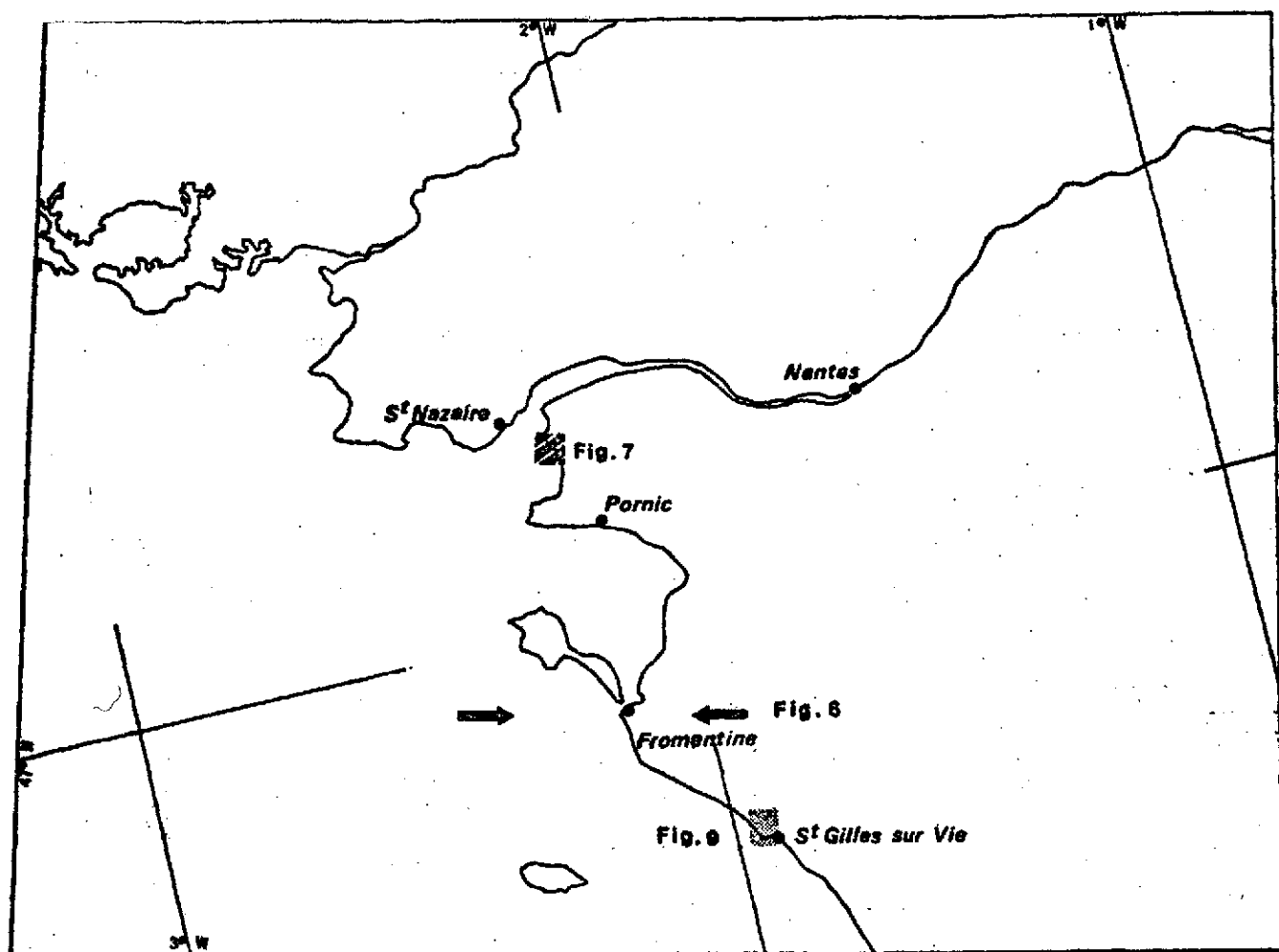


Figure 10. Sketch for localizing figures 6, 7, and 9.

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THE FRALIT PROGRAM
(ERTS-1)

Documents prepared for the occasion of
the thirtieth International Aeronautics and
and Space Exhibition

by

Teddy Husberg and Fernand Verger

Le Bourget

May, 1973

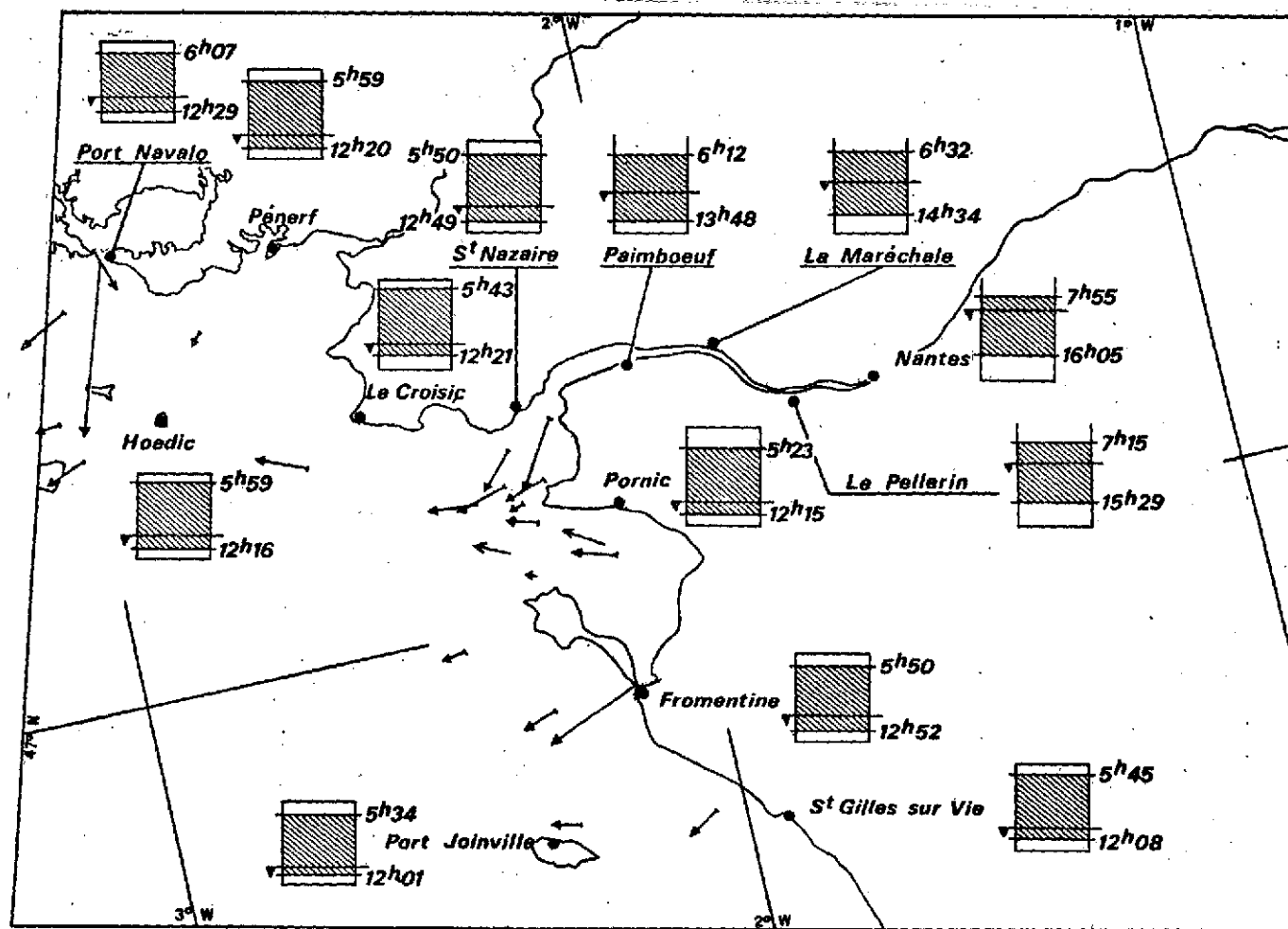
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FRALIT Program--ERTS-1

The following documents have been prepared on the basis of photograph E- 1066 10294 taken on September 27, 1972 by the scanning system (MSS) above the region of the Loire Depression.

A--The impression in composite colors has been obtained by using the negatives from four MSS channels. The negative of channel 4, highly reinforced, has been printed in red exclusively for sea or lake expanses. It offers a large number of details about coastal waters. The data for channel 5 have been conserved throughout the photograph and have been printed in blue; thus, highly turbid waters would appear in violet. The data for channel 6, printed in yellow, have only been conserved for land or island expanses where they are combined with the blue of channel 4. In this way, salt marshes are presented in green, dunes in blue when they are shifting dunes, and in yellow when they are covered with sea-pines. The limit between use of channel 4 or use of channel 6 has been based upon an equidensity of channel 7.

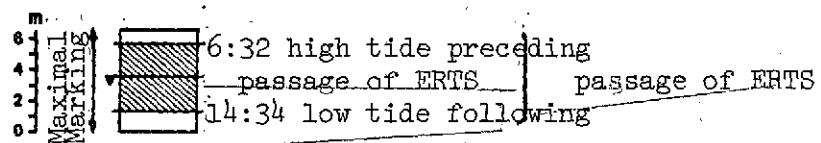
B--The following image, printed in blue, has been obtained by the equidensity method for channels 5 and 7 of the MSS System. The plottings (points) representing water are even more clear when the level of sedimentation is even higher. The plottings (lines) which most often border the land correspond to uncovered inlets that are still watery.



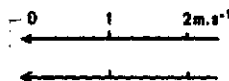
ERTS-1. FRALIT

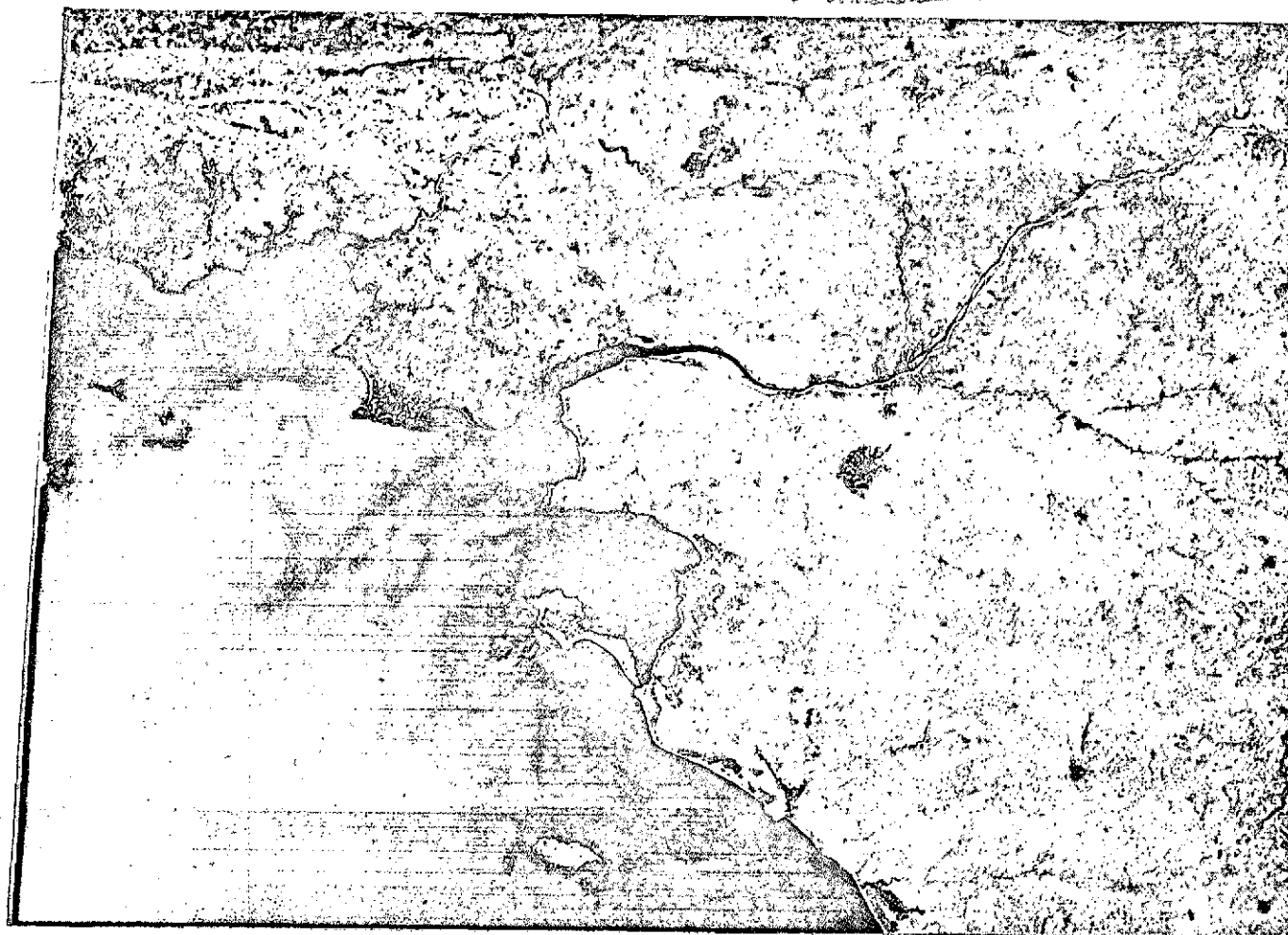
27 SEPT. 1972

E. 1066. 10 294



Tidal currents
Surface
At a 10-meter
depth





NATIONAL AERONAUTICS AND SPACE ADMINISTRATION IMAGE.

ERTS-1, FRALIT

27 SEPT. 1972

E 1066, 10 294



MSS 4



MSS 5



MSS 6